IMPROVING HURRICANE FORECASTS: SCIENTIFIC ADVANCES AND BUSINESS APPLICATIONS

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Presentation Structure

1. Why Forecast Hurricanes?
2. What is Seasonal Climate Prediction?
3. Scientific Advances:
   - *3.1 Seasonal Prediction of Atlantic, US and Caribbean Landfalling Hurricanes*
   - *3.2 Impacts of Global Warming*
4. Outlook for 2002 Atlantic Season
5. Future Developments and Conclusions
6. Business Applications

1. Why Forecast Hurricanes?

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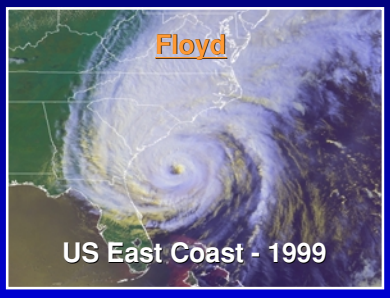
Substantial Impacts

- USA and Caribbean. Hurricanes rank as the region's costliest natural disaster.
- USA. Annual Hurricane damage bill 1925-2001 is estimated as US $ 5.1Bn (at 2001 $).



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Reduce Risk and Uncertainty

- **Substantial interannual variability exists in US tropical storm losses.** In 1999 and 1997, for example, the losses were US $ 8.2 bn and just US $ 0.16 bn respectively.
- Skilful long-range forecasts of seasonal tropical cyclone strike numbers will benefit society, business and government by *reducing the risk and uncertainty inherent to varying active and inactive storm seasons.*

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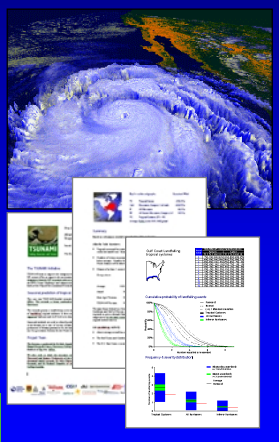
Tropical Storm Risk (TSR)

"Seasonal Prediction of Tropical Cyclones"

- Monthly updated forecasts for three ocean basins.
- Leads out to 10 months.
- Prediction of landfalling events.
- Forecast skill and uncertainty for 1987-2001 at monthly lead of choosing.
- Model design facilitates incorporation of dynamical prediction data.



UCL · Benfield Greig Hazard Research Centre · Crawford · Met Office · Royal & SunAlliance · BG Benfield Group

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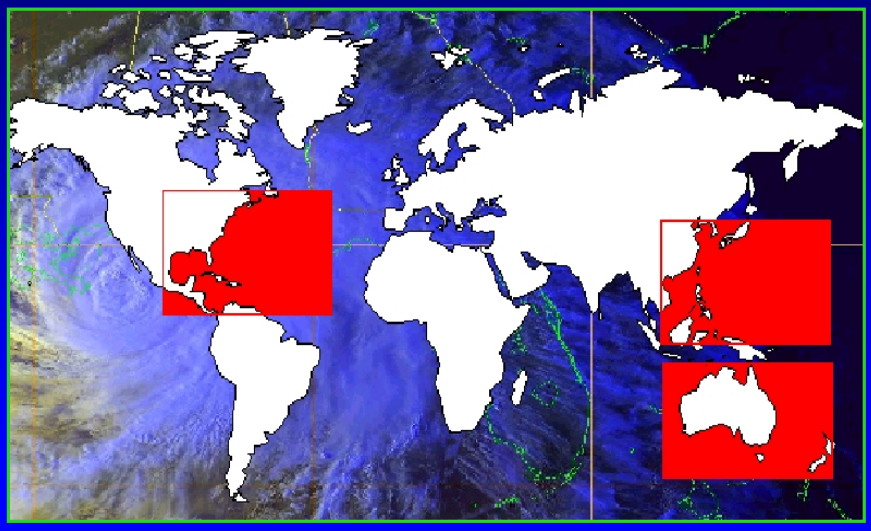
Basins Under Research



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2. What is Seasonal Climate Prediction?

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Weather and Climate

Weather - Day to day change in temperature, rainfall, windiness etc

Climate - Average state of the weather over periods longer than about a week:

- Intraseasonal Climate
- Seasonal Climate
- Decadal Climate
- Multi-Decadal Climate

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Limits of Weather Prediction

"Claims of skilfull predictions of day-to-day weather beyond 1-2 weeks have no scientific basis and are either misinformed or calculated misrepresentations of true capabilities".

American Meteorological Society
Policy Statement, 2001

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Seasonal Climate Prediction

- The prediction of anomalies in climate over seasonal (2-4 months) periods of time.
- Skill possible because atmosphere is forced by large scale (and predictable) anomalies in sea surface temperature and snow cover which evolve slowly.
- Seasonal Atlantic hurricane forecasts issued by:

  Gray/Colorado State University
  TropicalStormRisk.com (TSR)
  NOAA

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Intraseasonal Climate Prediction

- The prediction of anomalies in climate over intraseasonal (>7 days to 2 months) periods of time.
- Has received little scientific attention but there are sound grounds for expecting useful skill will come with concerted research effort.

  eg. Gray is introducing monthly hurricane forecasts for August and September.

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3. Scientific Advances

3.1 Seasonal Prediction of Atlantic, US and Caribbean Landfalling Hurricanes

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Methodology (1)

Statistical Model and Strategy

- Interannual variability in hurricane numbers modelled using a Gaussian model.
- Divide Atlantic basin into three sub-regions:
  - Main development region (10°N-20°N, 20°W-60°W)
  - Caribbean Sea and Gulf of Mexico
  - Extra-tropical north Atlantic.

Predictors Used

1. JUL-AUG-SEP (JAS) forecast 925mb U-wind for 7.5°N-17.5°N, 30°W-100°W.
2. AUG-SEP (AS) forecast SST for Atlantic hurricane main development region 10°N-20°N, 20°W-60°W.

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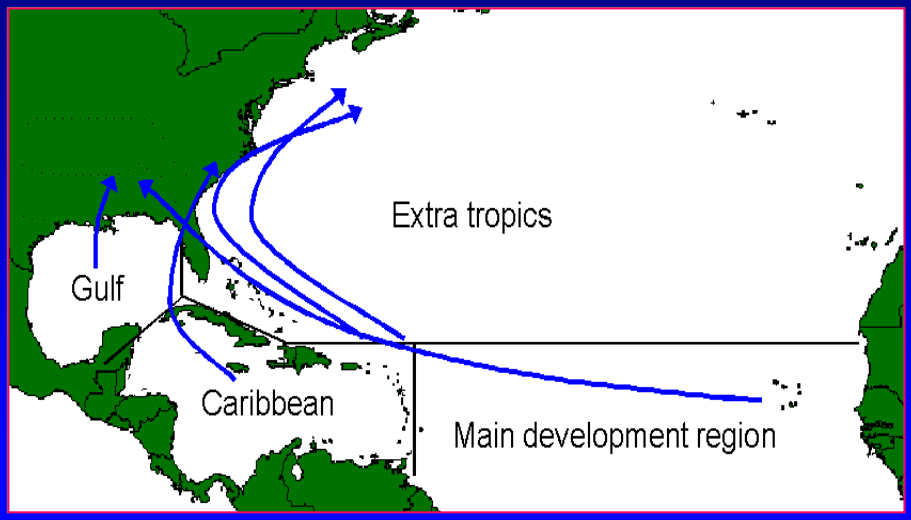
Forecast Sub-Regions



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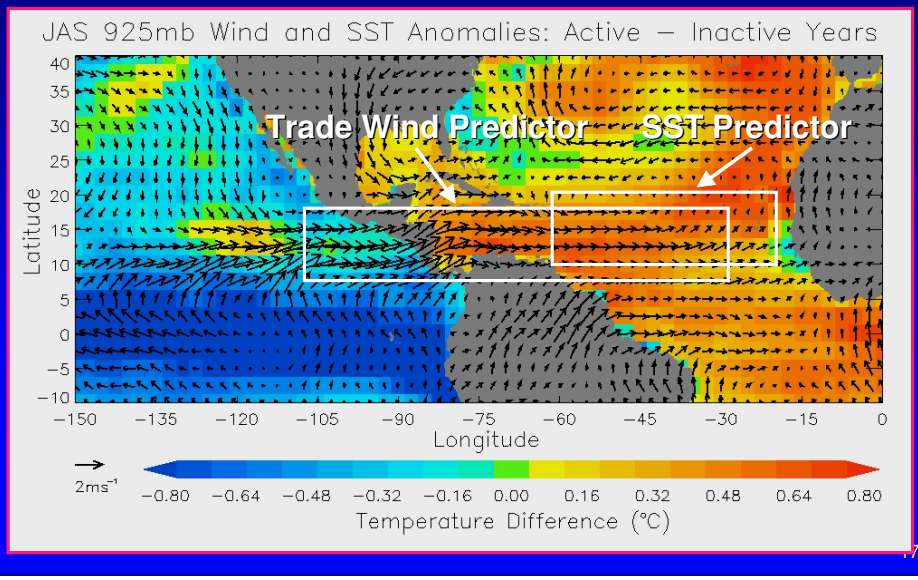
Atlantic Hurricane Predictors



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Methodology (2)

Forecast Models

- Simulated real-time forecast skill for 1987-2001 assessed by constructing models always with prior data.
- Leads from 0 to 10 months examined.

Skill Score and Uncertainty

1. Employ percentage improvement in RMSE over a climatological forecast (SS_{Clim} (%)):

$$SS_{Clim}\ (\%) = (1 - RMSE_{Fore}/RMSE_{Clim}) \times 100$$

1. Compute 95% confidence intervals on skill using the bootstrap method.

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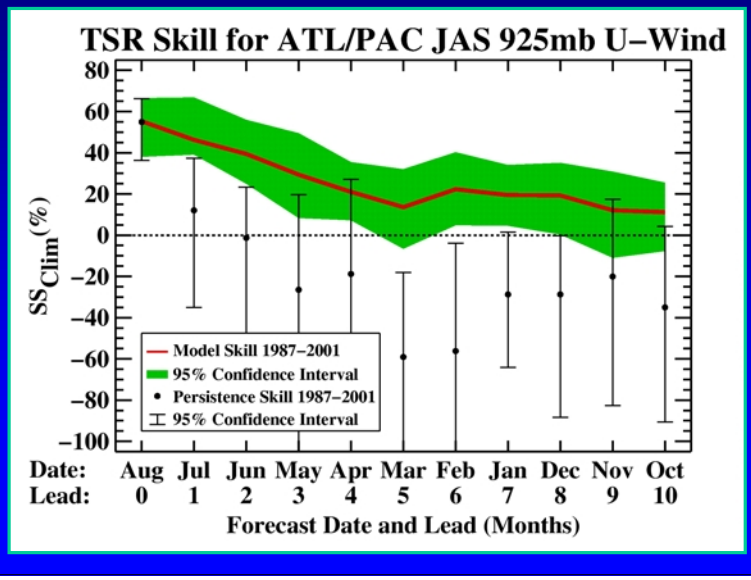
Trade Wind Speed Forecast Skill for JAS



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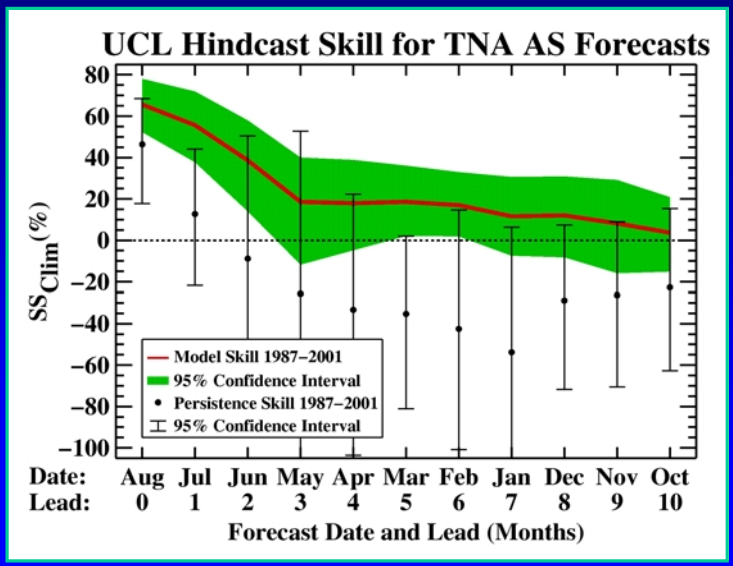
Tropical North Atlantic SST Forecast Skill for AS



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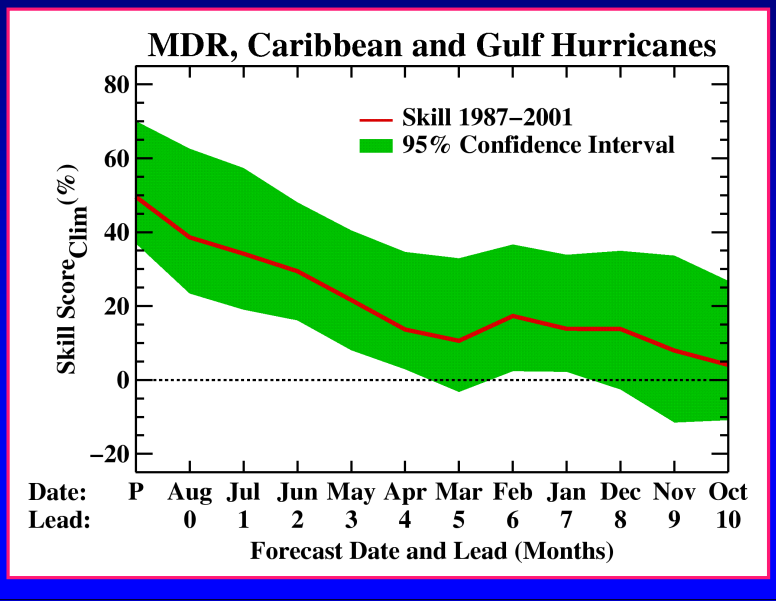
Seasonal Skill - Example 1



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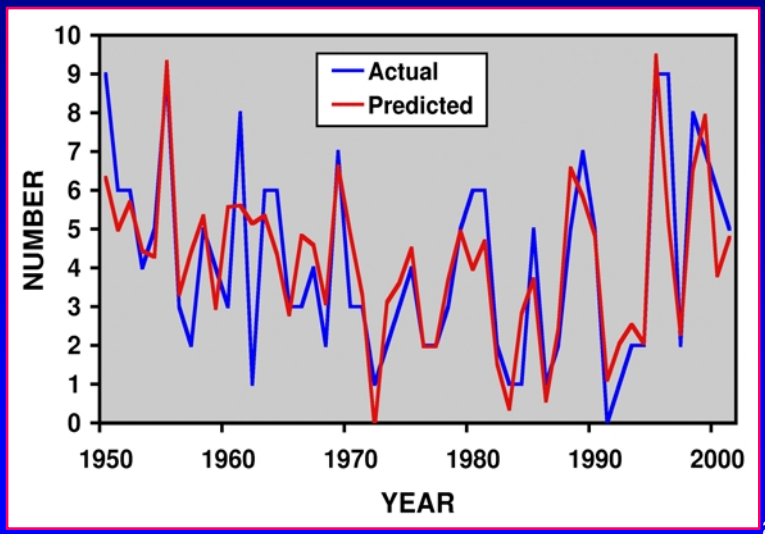
Hurricane Numbers 1950-2001
Tropical Atlantic, Caribbean Sea and Gulf

Perfect Predictors

$R^2 = 0.67$



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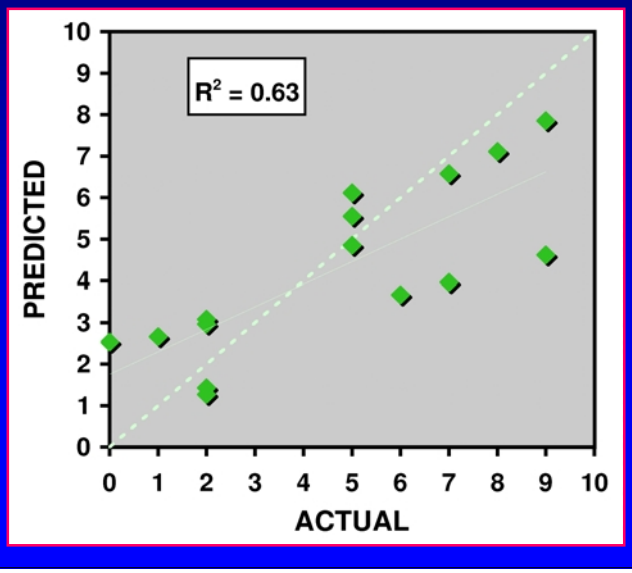
Hurricane Numbers 1987-2001
Tropical Atlantic, Caribbean Sea and Gulf

August Forecast



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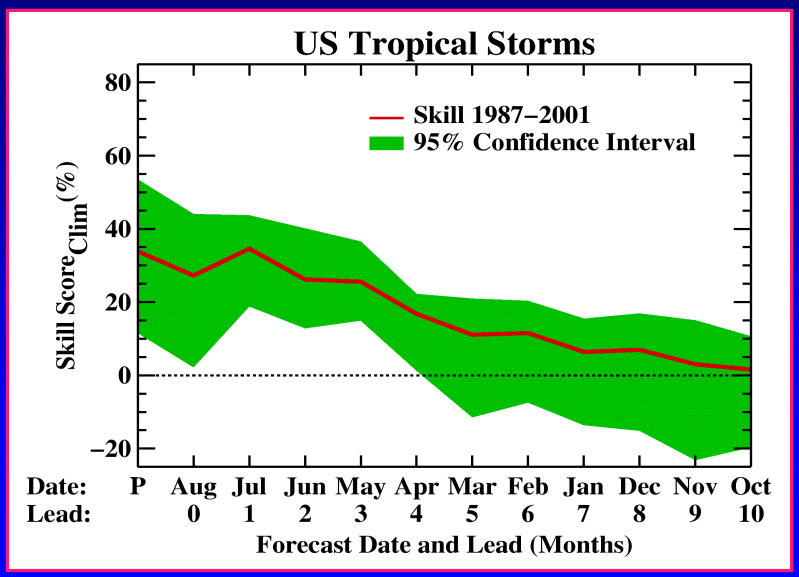
Seasonal Skill - Example 2



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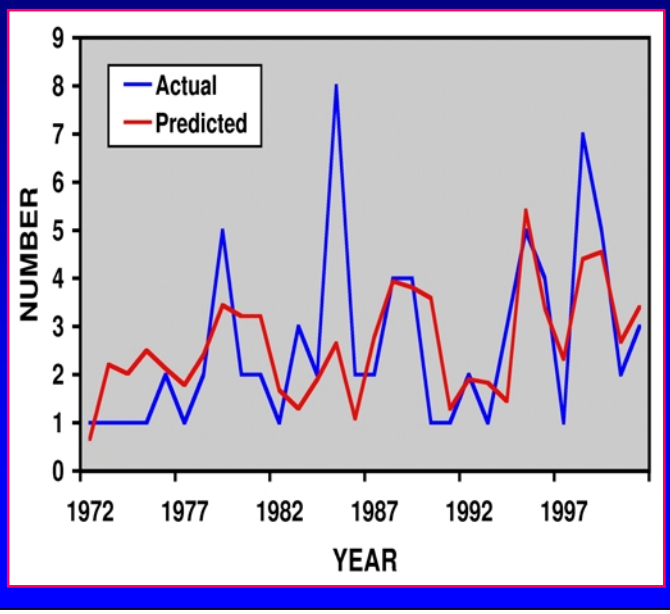
US Tropical Storm Strikes

1972-2001

Perfect Predictors

$R^2 = 0.36$



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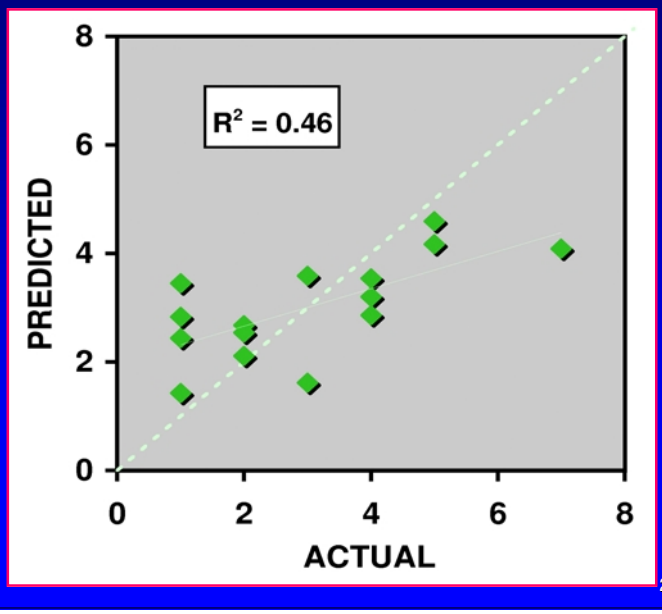

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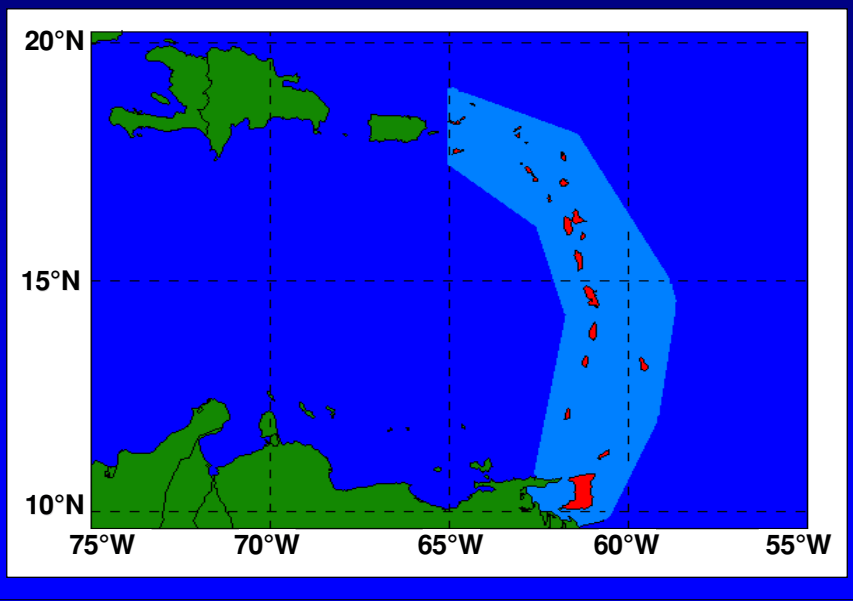
Caribbean Lesser Antilles



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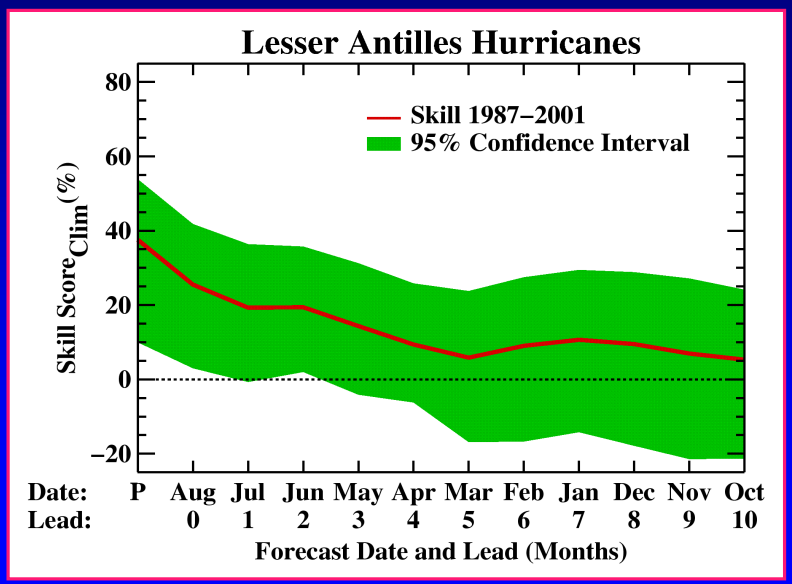
Seasonal Skill - Example 3



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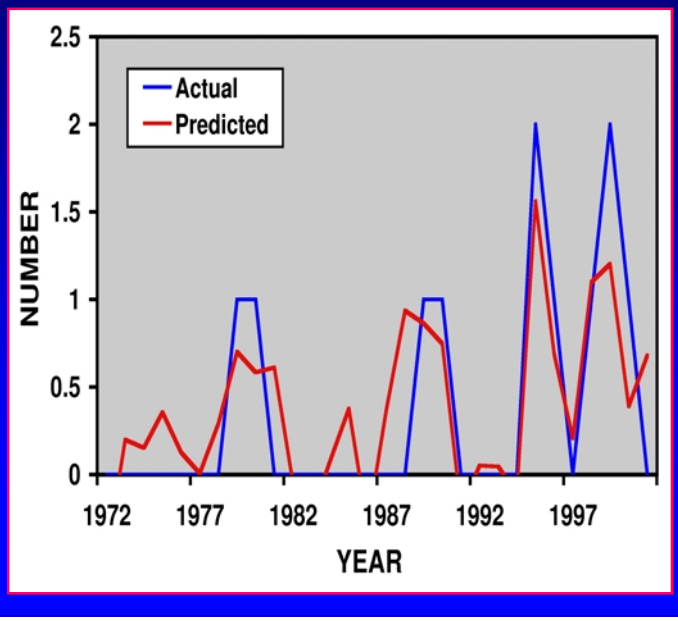
Lesser Antilles Hurricane Strikes

1972-2001

Perfect Predictors

$R^2 = 0.60$



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TSR/Gray Skill Comparison

Strength	Lead	Start Year	End Year	PVE		$RMSE_{CI}$ (%)		MAE_{CI} (%)	
				TSR	Gray	TSR	Gray	TSR	Gray
H	0	1987	2001	67	45	43	25	43	22
H	2	1987	2001	44	22	21	13	17	14
H	4	1995	2001	30	0	20	10	19	12
H	8	1992	2001	23	0	17	0	15	0

- TSR outperforms Gray at all leads using all skill measures.

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TSR/Gray Skill Comparison

Strength	Lead	Start Year	End Year	PVE		$RMSE_{CL}$ (%)		MAE_{CL} (%)	
				TSR	Gray	TSR	Gray	TSR	Gray
TS	0	1987	2001	71	61	45	37	45	35
TS	2	1987	2001	68	31	33	18	41	16
TS	4	1995	2001	22	0	22	3	26	0
TS	8	1992	2001	19	0	13	0	12	0

- TSR outperforms Gray at all leads.
- However, one can not conclude the TSR model is better than the Gray model since the latter has changed with time.

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3.1 Summary

- TSR has developed an innovative and skillful forecast methodology for the seasonal prediction of Atlantic hurricane activity.
- Skill to 95% confidence exists from:

  Early January for Atlantic hurricane numbers
  Early April for US tropical storm strikes
  Early June for Lesser Antilles hurricane strikes.

- These forecasts will help to reduce risk and uncertainty.

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Further Information

- **Further information** on the TSR forecast methodology, simulated real-time forecast skill 1987-2001 and on TSR in general may be obtained from ***www.tropicalstormrisk.com***.
- To receive free notification of forecasts please register at **www.tropicalstormrisk.com**.

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3. Scientific Advances

3.2 Impacts of Global Warming

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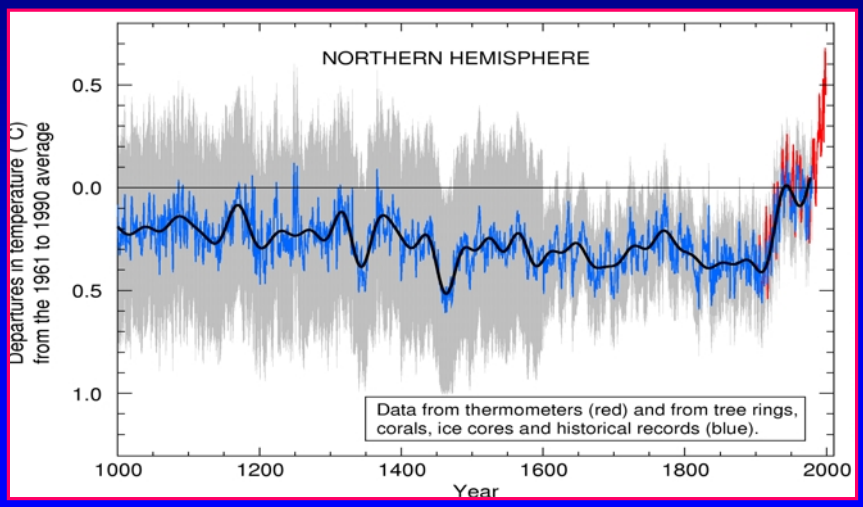
Earth's Surface Temperature Record

The Past 1,000 Years



(Adapted from IPCC, 2001)

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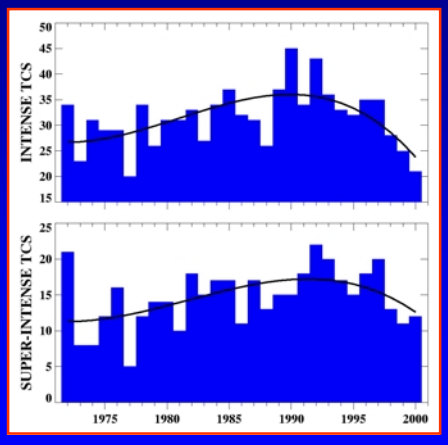
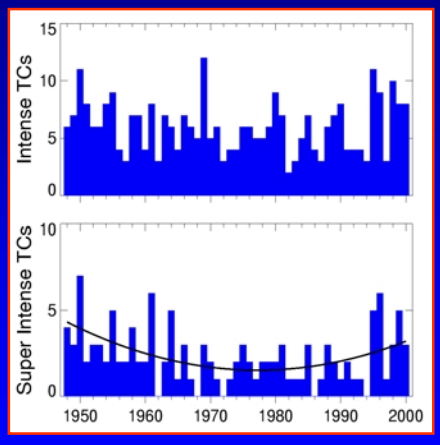
Trends in Intense Tropical Cyclone Numbers

Northern Hemisphere 1971-2000



Atlantic Basin 1948-2000



Intense TCs = 1-min Sustained Winds > 73 mph

Super Intense TCs = 1-min Sustained Winds > 110 mph

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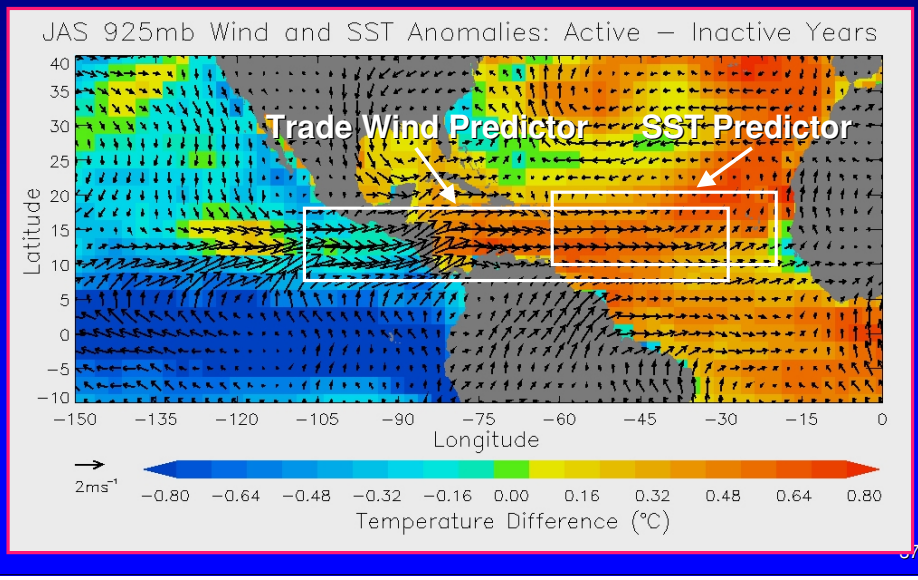
Atlantic Hurricane Predictors



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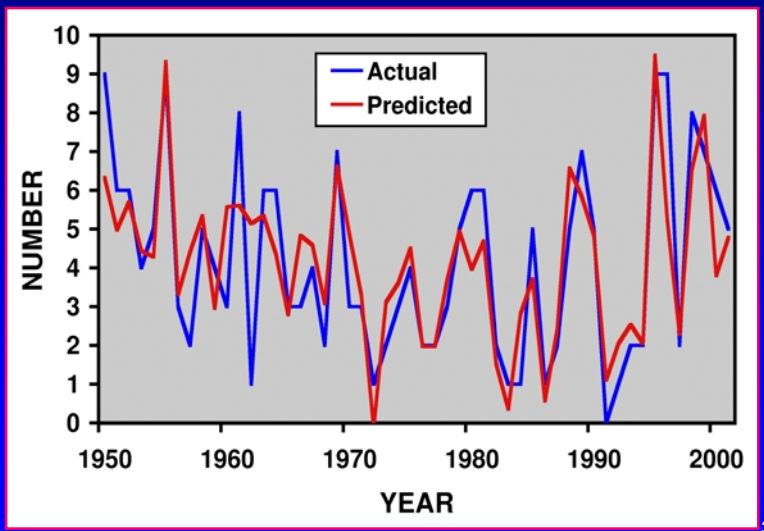

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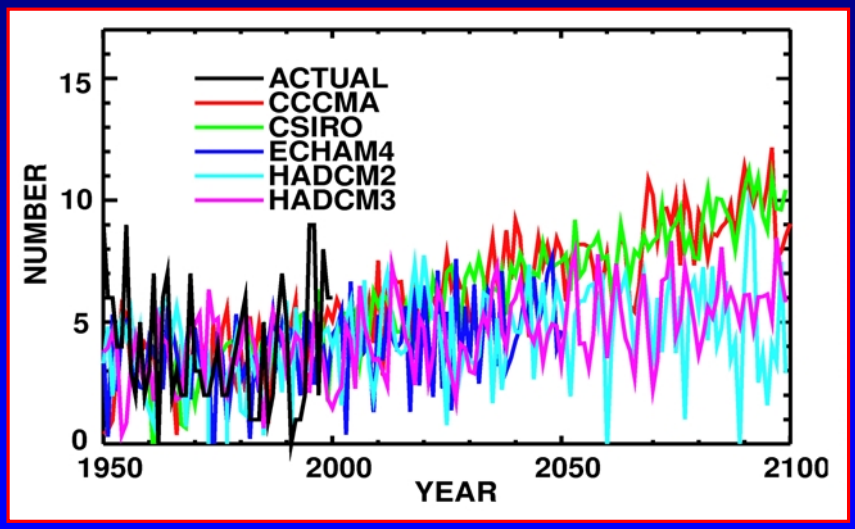
Future Projections for Tropical Atlantic, Caribbean and Gulf Hurricane Numbers



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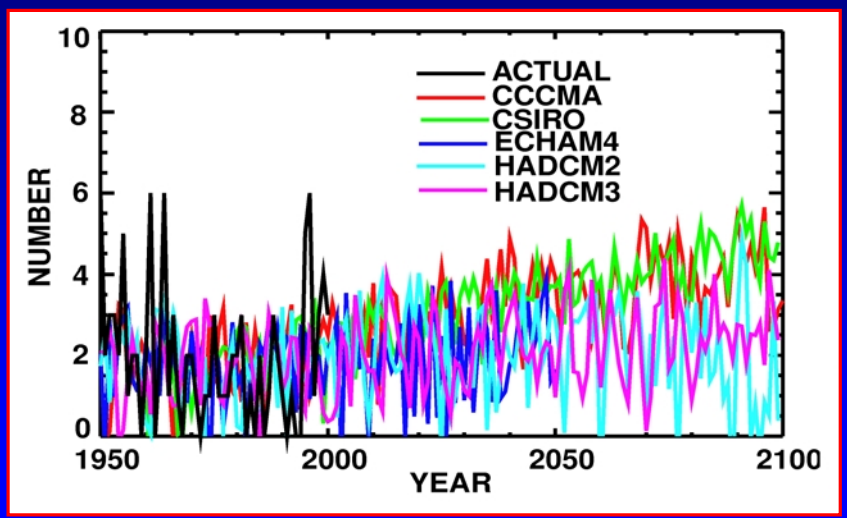
Future Projections for Tropical Atlantic, Caribbean and Gulf Intense Hurricane Nos



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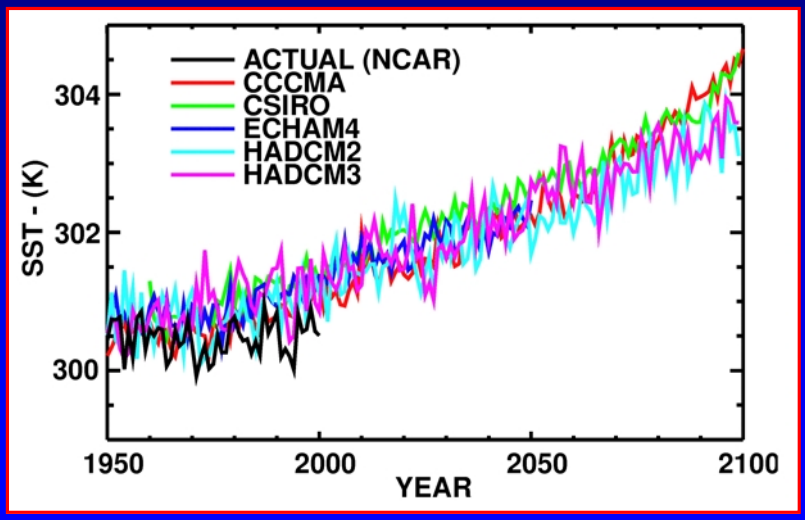
Future Projections for Tropical Atlantic SST



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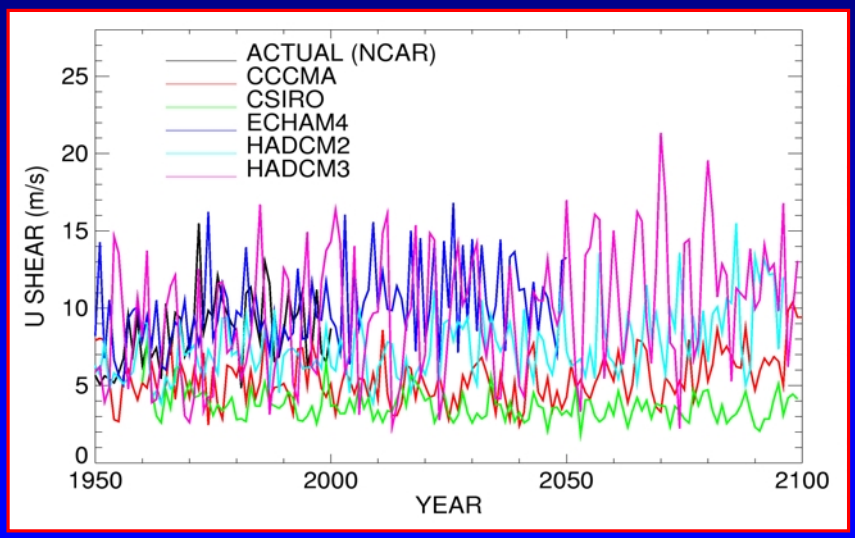
Future Projections for Tropical Atlantic Vertical Wind Shear



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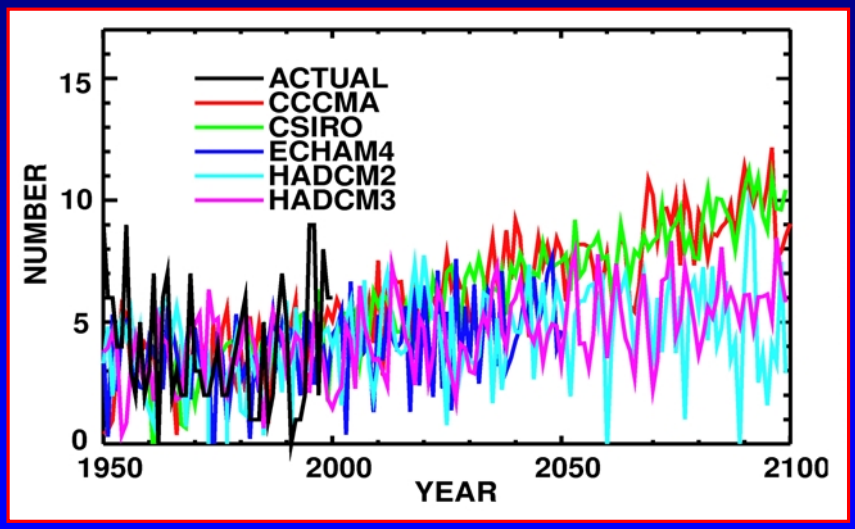
Future Projections for Tropical Atlantic, Caribbean and Gulf Hurricane Numbers



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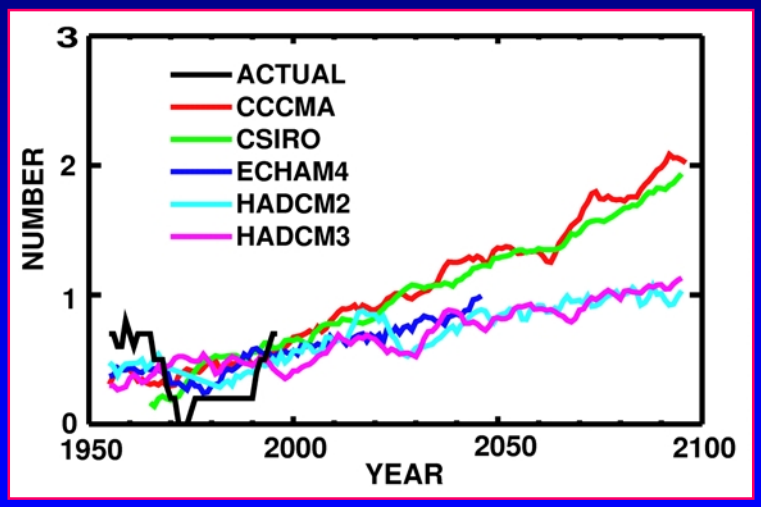
Future Projections for Lesser Antilles Hurricane Strikes



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3.2 Summary

- The number of Atlantic, US and Caribbean landfalling hurricanes may rise slowly due to global warming.
- However, the change in the mean number is likely to be small (10-20%) compared to the current range of natural year-to-year variability.
- The majority of future changes in US and Caribbean hurricane losses will continue to result from natural interannual and decadal variability.

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4. Outlook for 2002 Atlantic Hurricane Season

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Predictions for 2002 Atlantic Season

Atlantic Total Numbers 2002				
		Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (±SD) (1992-2001)		11.5 (±4.1)	6.9 (±2.9)	2.9 (±2.0)
Average Number (±SD) (1972-2001)		9.5 (±3.6)	5.7 (±2.4)	2.1 (±1.5)
TSR Forecasts (±FE)	5 Apr 2002	11.2 (±3.1)	6.3 (±2.3)	2.4 (±1.9)
	6 Mar 2002	12.5 (±3.6)	7.2 (±2.5)	2.8 (±1.9)
	6 Feb 2002	13.6 (±3.5)	8.0 (±2.5)	3.2 (±1.8)
	10 Jan 2002	13.1 (±3.6)	7.7 (±2.6)	3.0 (±1.8)
	3 Dec 2001	13.0 (±3.6)	7.5 (±2.5)	3.0 (±1.6)
Gray Forecasts	5 Apr 2002	12	7	3
	7 Dec 2001	13	8	4

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Summary and Next Forecast

- For the 2002 season we anticipate activity above the 30-year average but below the 10-year average.
- During the summer we expect ENSO to be weakly positive (slight -ve factor), the trade winds to be average (neutral factor) and Atlantic SSTs to be warmer than average (+ve factor).
- Our next (May) forecast update for Atlantic, US and Caribbean landfalling hurricanes in 2002 will be released on 7th May 2002.

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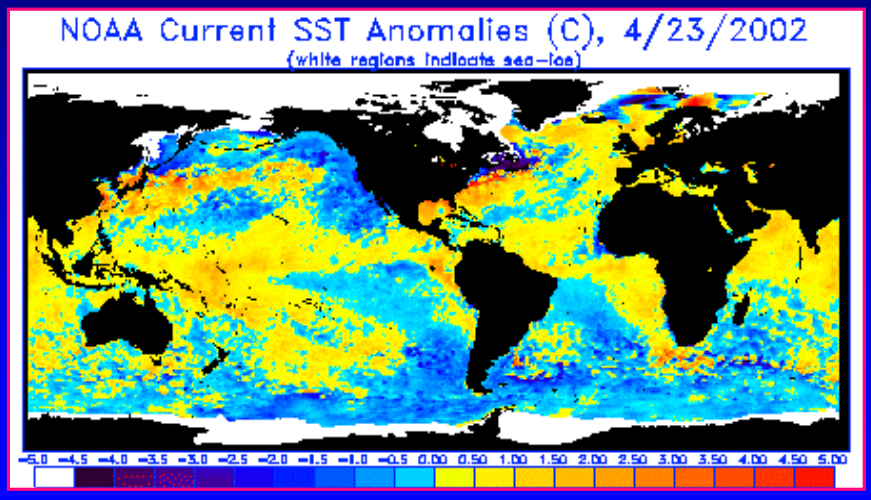
Current ENSO Conditions



(Image courtesy of NOAA)

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5. Future Developments and Conclusions

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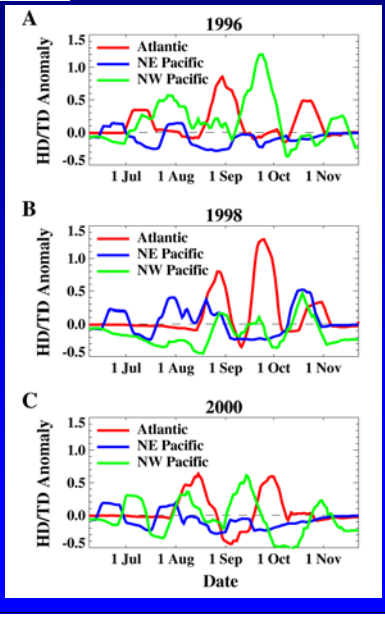
Intraseasonal Activity



- Figure shows intraseasonal hurricane and typhoon activity observed in the Atlantic, NE Pacific and NW Pacific tropical cyclone basins in 1996, 1998 and 2000.
- The instraseasonal period varies with year from ~50 days (1996) to ~30 days (1998).
- Beneficiaries of skilful intraseasonal hurricane forecasts might include risk management companies and emergency managers.

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Proposal for Operational Intraseasonal Forecast Model

- Sound grounds for believing skill is present out to at least ~20 days.
- Develop statistical operational forecasting model for intraseasonal Atlantic hurricane activity at pentad (5 day) leads out to 45 days.
- Assess the model skill for each region through rigorous simulated real-time forecasting over the period 1992-2001.

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Conclusions

- Seasonal hurricane forecast skill is already useful ($r > 0.5$) at leads out to 4 months.
- Seasonal climate prediction is still an innovation in meteorology. There are sound grounds for expecting this skill will improve with further research.
- Management professionals in catastrophe response will be well advised to monitor developments in seasonal (and intraseasonal) forecasting over the next few years.

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